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Review

An update and review of simulation in urological training

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ABSTRACT

Simulation, if appropriately integrated into surgical training, may provide a time efficient, cost effective and safe method of training. The use of simulation in urology training is supported by a growing evidence base for its use, leading many authors to call for it to be integrated into the curriculum. There is growing evidence for the utilisation of part task (technical skills) simulators to shorten the learning curve in an environment that does not compromise patient safety. There is also evidence that non-technical skills affect patient outcomes in the operating room and that high fidelity team based simulation training can improve non-technical skills and surgical team performance. This evidence has strengthened the argument of surgical educators who feel that simulation should be formally incorporated into the urology training curriculum to develop both technical and non-technical skills with the aim of optimising performance and patient safety.

1. Introduction

Changes in the modern working environment and training patterns have resulted in the need for surgical trainees to achieve competency in a growing number of complex surgical procedures,[1] with reduced training hours[2] and a growing expectation from patients. Given these radical changes in surgical training, the traditional Halsteadian apprenticeship model of "*see one, do one, teach one*" is no longer considered adequate; surgical trainers must therefore look to novel and effective ways to better deliver training.

The majority of surgical errors occur in the operating room (OR) and several studies have identified that an increased number of complications occur during the surgeon's initial learning curve.[3,4] The awareness of these dangers, and the fact that patients are no longer happy to be used as training objects, has resulted in a call to move "the learning curve out of the operating room" into a safe and controlled environment.[5]

Simulation has emerged as a tool that, if appropriately integrated into surgical training, may provide a time efficient, cost effective and safe method of training.[6] The value of simulation based training is recognised by both urology trainers and trainees[7,8] and in 2008 the Residency Review Committee in surgery decreed that all training programs within the US should "include simulation and skills laboratories".[9] Many studies in surgical simulation support this view and there are several randomised trials that have directly assessed whether simulation training improves performance in the operating room (Table 1). With only a few exceptions these have demonstrated significant improvements in performance with simulation training.

The realisation of the importance of simulation in urology has led many authors to call for it to be formally integrated into the curriculum.[16,17] In the United Kingdom, SIMULATE, a national simulation based training program has been developed and validated[18] and in the US simulation based training and assessment forms the basis of the Fundamentals of Laparoscopic Surgery and Fundamentals of Endoscopic Surgery programs.[19] It is even now possible to include simulated procedures onto the online logbook used by UK surgical trainees (Intercollegiate Surgical Curriculum Program Website www.iscp.ac.uk).

The majority of the surgical and urology literature on simulation has focused on the use of simulation as a tool for teaching and assessing technical (procedural) skills. Although errors occur during the surgical technical learning curve, the majority of errors in surgery are the result of deficiencies in non-technical skills such as communication, teamwork and decision making.[3,20] These deficiencies in non-technical skills have led several authors and government bodies to demand focused training to address this skills gap.[21,22] Team based simulation has emerged as a powerful training tool to help achieve this.[22]

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Table 1
Examples of randomised trials assessing the skill transfer from simulators to the operating room.

Study	Simulator platform used for training	Study design	Results
Hamilton et al., 2002[10]	MIST-VR™ and Laparoscopic box trainer	Lap Chole on patients performed before and after simulation training on either VR or box trainer	Performance significantly improved with training on both the box trainer and VR simulator.
Garatcharov et al. 2004[11]	MIST-VR™	Lap Chole on patients performed before and after VR training or no training (control)	Simulation trained group performed significantly better than control.
Sedlack et al., 2004[12]	VR sigmoidoscopy simulation	Flexible sigmoidoscopy on patients performed after simulation training or no training (control)	Simulation trained residents caused less patient discomfort. No measurable difference in performance
Larsen et al., 2009[13]	LapSIM™	Lap salpingectomy on patients after simulation training or normal clinical experience (control)	Simulation trained group performed significantly better and more quickly than control.
Kallstrom et al., 2010[14]	PelvicVision™	TURP on humans before and after simulation or no simulation training (as part of a course)	No significant differences – but a trend for improved performance with simulation
Franzeck et al., 2012[15]	ProMIS™ and LapSIM™	Camera navigation skills on patients following simulation or supervised practice on patients	Simulation trained group learned quicker than OR trained group.

The aim of this article is to review simulation tools in urology for both technical skills training and non-technical skills (NTS) training and provide an overview of the potential uses for simulation in assessment.

2. Principles of simulation training

Simulation training is not simply about buying a simulator and asking trainees to use it for a set number of hours before being let loose in the OR – training must be effectively integrated into the curriculum and it should be performance based, so that trainees progress when they reach a set standard rather than complete a set number of procedures/training hours. It is beyond the scope of this article to discuss the all the principles of curriculum design but the initial step is to identify training needs, then design and implement the training curriculum and finally to assess measurable outcomes.

Several specific aspects of simulation training have been shown to improve learning. In 2010 McGahie et al. published a comprehensive review of simulation based medical education by reviewing simulation literature from 1969 to 2009.[23] Their paper provides a good starting point for trainers interested in simulation and identifies 12 best practices that can enhance learning during simulation training. The top five are listed below:

1. Feedback. Accurate, timely, feedback focused on improving performance has been shown to improve learning in numerous educational contexts and the same is true for simulation. Several simulators are able to record performance metrics and provide automatic feedback.
2. Deliberate Practice. This principle, based on work by psychologist K Anders Ericsson, is frequently referred to in the surgical literature and refers to repetitive, focused practice with appropriate feedback, aiming to achieve a mastery standard.
3. Curriculum Integration. Simulation is not a substitute for clinical based education but should delivered in a timely and appropriate way to complement surgical training.
4. Outcome Measurement: Educators require valid and reliable ways to measure performance to provide feedback and make judgements about trainees. This can also allow performance based curricular to be developed.
5. Simulation Fidelity: The fidelity (realism) of the simulator should match the learning goals – for example, junior trainees may need less realistic simulators for basic skills training than more advanced trainees require for full task simulations.

In addition to these general educational principles there are several practical aspects to consider. Ahmed et al. describe a framework of how to develop simulation training in urology and discuss several challenges and solutions.[17] They summarise the critical factors with five P's:

- **P**eople – involvement of leaders, faculty, management and administrators.
- **P**lace – centralised training facilities vs. hub and spoke models
- **P**ounds – adequate funding
- **P**ositioning within the curriculum and the surgical rota

…….and finally **P**roducts – the simulators themselves.

It can therefore be seen that when designing simulation based training the surgeon has to understand the principles of simulation based education, know how to establish a training programme and finally choose the appropriate simulators.

3. Simulators in urology

Urology is particularly well suited to simulation as many operations are endourological (e.g. cystoscopy, TURP, ureteroscopy) or laparoscopic (e.g. nephrectomy, prostatectomy). In addition to numerous laparoscopic simulators there are several urology specific simulators available as shown in Table 2. With advances in simulation technology and developments in surgical practice new simulators are constantly being developed. Simulators include mechanical (synthetic) simulators, virtual reality (VR) simulators, hybrid simulators (mechanical models with computer tracking), human cadavers and animal models – all of which have advantages and disadvantages in terms of cost, facility and faculty requirements, and realism (fidelity).

Most authors agree that there should be evidence showing that a given simulator is a valid educational tool before it is widely adopted in training.[24,25] However with advances in simulation technology and the constant development of new simulators it is difficult for research to keep pace with simulator development. This means that older simulators, although often less technologically advanced, tend to have a better evidence base, as there has been more time to study them. Furthermore, (probably due to financial and ethical constraints) animal and cadaveric based simulation training has been less well researched.

Surgical educators have to decide which of the myriad of available simulators they should integrate into the urology curriculum and, when there is little available evidence, must rely on their judgement. Fortunately there are a growing number of published studies evaluating urology simulators.

Validation studies assess whether a given simulator is a valid educational tool but there are no universally accepted criteria on

Table 2
Urology simulators (for more detail of validation studies see references 27–29) (VR = virtual reality).

Procedure	Simulator type	Description of simulator	Face, content and construct validity demonstrated	Evidence of skills transfer to the OR
Cystoscopy	VR	URO mentor (Symbionix)	Yes	
		URO trainer	Yes	
	Bench	Limbs and things	No	
		Mediskills		
TURP	VR	Pelvic vision	Yes	Yes[a]
		UW TURP trainer	Yes	
	Bench	Limbs and things	No	
TURBT	VR	URO mentor (Symbionix)	Yes	
	Bench	Limbs and things	No	
Ureteroscopy	VR	URO mentor (Symbionix)	Yes	Yes
	Bench models	Limbs and things	Yes	
		Mediskills	Yes	
		University Toronto model	Yes	
PCNL	Virtual reality	PERC mentor (Symbionix)	Yes	
	Bench	Limbs and things, mediskills	No	
Laparoscopic Nephrectomy	VR	Procedicus MIST (Mentice)	Yes	
		LAP mentor (Symbionix)	Yes	
Vasosvasotomy	Bench	Silicon tubing	No	
Robotic surgery	VR	dV-trainer (Mimic)	Yes	
		dVSS (Intuitive Surgical)	Yes	
		RoSS (simulated surgical systems)	No	
		SEP (Sim Surgery)	Yes	
		ProMIS (CAE healthcare)	Yes	
		Surgical SIM RSS (METI)	Yes	
	Bench	Partial nephrectomy model	No	
TRUS and prostate biopsy	VR	University of Western Ontario	No	

[a] Participants did not statistically improve in all aspects of performance following simulation training.

how to validate a simulator. Consequently there are methodological variations between published studies and some authors have highlighted the need for a consensus regarding validation methodologies.[25,26] Subjective methods of validation include face and content validation where study participants rate aspects of the simulator using questionnaires (usually with Likart scales). Objective studies of validity include construct validity (whether a simulator can differentiate between experts and novices), criterion validity (comparison of the simulator with a gold standard) and predictive validity (comparison of simulator performance with real OR performance). Some studies have also evaluated the reliability of performance metrics and looked at trainees' learning curves; this additional information can provide data to help plan training and to develop performance based simulation programmes.

It is generally considered that the minimum evidence for widespread simulator use should include face, content and construct validity and this is even better if data on reliability and cost effectiveness are provided.[25] Three systematic reviews have specifically evaluated the evidence for simulators in urology. In 2008 Schout et al. published a review of endourology simulators and in 2011 Ahmed et al. undertook a similar review but included all relevant urological simulators.[27,28] Recently Abboudi et al. published a review evaluating the robotic simulators available for urology.[29] These three reviews identify and describe numerous available urology simulators and several of these have proven face, content and construct validity as shown in Table 2. Some of these studies have also shown that novices (usually junior doctors or medical students) can improve simulator performance with practice and that this can transfer into improved performance on animal models. Importantly two urology simulators have been used to show that simulator training for junior residents can improve surgical performance in the OR (see Table 2).

It is logical to use simulation during the early part of the learning curve so it is not surprising that studies to date have assessed learning curves in novices and junior trainees. Evidence to date therefore supports simulation more strongly in this setting — however with more advanced simulators that can recreate complex surgery it is likely that in future simulation will be used more throughout urology training. It is possible that future simulators may be even be used to teach higher cognitive skills such as intraoperative decision making.

The well-validated simulators in Table 2 have the best evidence base to support their use but where more than one simulator is available for a given procedure there are no comparative studies to help inform trainers. Further research is needed to compare available simulators and to assess the growing number of new simulators being produced. Educators must therefore consider available evidence but also use their judgment to evaluate how well a given simulator can add to a specific training curriculum — this will not only depend on the simulator but on individual training needs, available facilities, faculty support, and funding.[17]

4. Simulation for non-technical skills training

Surgery, perhaps more than any other branch of medicine, has been defined by the technical skills of its clinicians and this has meant that acquisition of these skills has taken primacy over other training requirements. However, we know that the practice of surgery contains far more than high quality technical skills — non-technical skills (NTS) such as communication and decision-making are vitally important. Extensive human factor research has shown that NTS significantly affect team performance,[3,20] surgical skills[30] and patient safety in the operating room. In fact deficiencies in NTS cause more errors in the OR than deficiencies in surgical skill.[20] So why doesn't surgical training, like the aviation industry, focus on NTS?

Surgical training is starting to change and NTS training and learning objectives have already been introduced into the curricular for the Australasian College of Surgeons,[31] the American College of Surgeons Association of Program Directors in Surgery (ACS-APSD) and the Team Strategies and Tools to Enhance Performance and Patient Safety (team STEPS).[30]

Table 3
Examples of non-technical skills for the operating room (adapted from 32 to 34).

Non-technical skill	Description	Examples of good behaviours
Communication (social skill)	Ability to clearly deliver and receive information	Clear and concise instructions Waits for check back
Teamwork (social skill)	Co-ordination of activates to optimize performance.	Supportive of other team members Values and utilises contribution of other team members
Leadership (social skill)	Ability of the team leader to optimise team performance.	Does not permit corner cutting Utilisation of resources Manages time well
Situational Awareness (cognitive skill)	Ability of the individual or team to accurately perceive the environment	Continuous monitoring of patient parameters Verbalises what is needed in the future
Decision Making (cognitive skill)	The process of reaching a judgment or deciding on a course of action	Verbalises problem Communicates & implements decision Reviews/monitors outcome

Non-technical skills can be classified into cognitive factors (e.g. decision making, situational awareness, planning) social factors (e.g. communication, teamwork, leadership) and personal resource factors (e.g. ability to cope with stress and fatigue).[32] Several studies have been conducted to identify the NTS and related behaviours that specifically affect performance in the OR (Table 3).[33,34] These studies have also developed validated scoring systems that can be used for research, to provide feedback during training and to provide an educational framework to describe these skills to surgeons.

These NTS are not innate personality traits but can be taught and developed through training. Research in medicine and other safety critical industries (e.g. aviation, nuclear power, military) has shown that training can improve NTS and team performance in the workplace.[32] Several strategies have been used to improve NTS but in surgery, as in other industries, simulation based team training has emerged as one of the best ways to achieve this.[32,35,36]

Team based training typically uses high fidelity simulated environments to represent clinical scenarios – simulated OR scenarios can be developed by combining a high fidelity human patient manikin with a part task surgical trainer in a simulated OR environment. Modern manikins can reproduce realistic patient physiology while a part-task surgical simulator simulates a technical aspect of the procedure. The aim is to create an environment with enough realism for the surgical team to participate in the simulation, to suspend disbelief, and display realistic team behaviours that can be discussed and analysed during subsequent debriefing. Training can be done in a simulated OR, in the real OR using simulators (in situ training) or even in a mobile inflatable operating room e.g. an "igloo simulator" (Fig. 2).[37]

Careful attention to scenario design,[32] training as a multidisciplinary team[23,38] and use of video feedback can help maximize learning in these contexts. However the post-scenario debriefing has consistently been identified as the most important aspect of the learning experience.[23,39] A skilled facilitator can provide feedback, encourage learners to analyse specific behaviours and NTS, create a safe learning environment and help learners to apply their knowledge to work based settings.

Several groups have analysed the effectiveness of this type of training in surgery and both Lee et al. and Gettman et al. have looked at high fidelity OR simulation training for urologists.[40,41] Both studies used simulated laparoscopic nephrectomy within a high fidelity simulated OR. In the study by Lee et al. participants felt the training was useful and the debriefing sessions were important learning experiences, which therefore established face validity. Interestingly, technical performance, but not NTS performance was related to the seniority of the trainees suggesting that even experienced residents are in need of NTS training.

In the study by Gettman et al. face validity was also established for the developed scenarios and additional questionnaires looking at the individual aspects of the simulation established content validity. Furthermore, significant improvements in teamwork and team performance were observed in the simulated scenarios following training. These two studies therefore support this type of NTS training in urology.

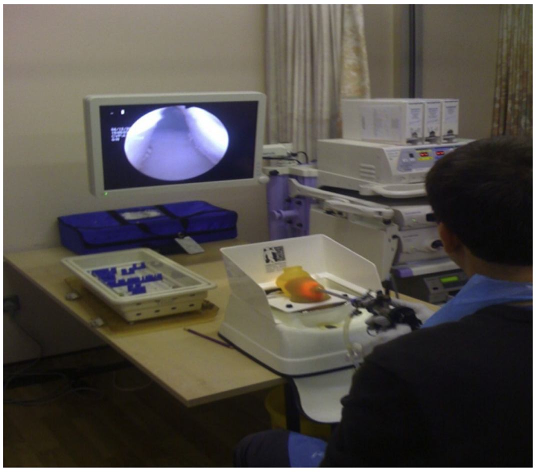

Fig. 1. TURP simulation training using a mechanical TURP model.

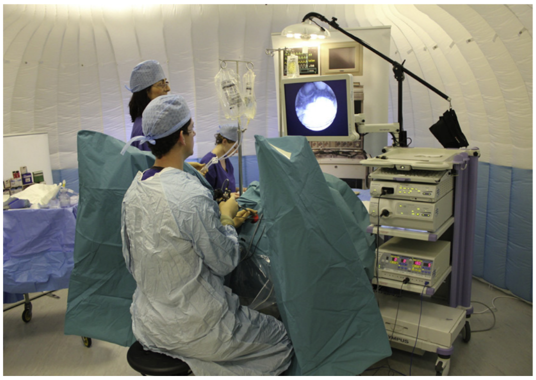

Fig. 2. Distributed simulation – a blow up room housing a simulated operating suite set up for a simulated trans-urethral resection of the prostate (using the model from Fig. 1).

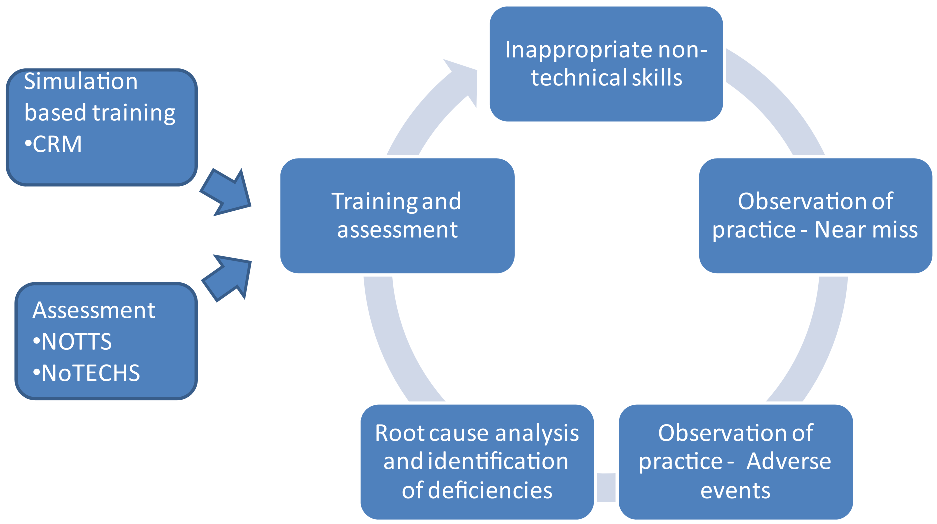

Fig. 3. Identification of learning needs for non-technical skills training. CRM = crisis resource management team based training, NOTTS and NoTECHS = validated NTS scoring systems for surgery.

Studies in other surgical specialties have found that team based NTS training results in improved simulator performance but no studies have directly evaluated whether this improvement can be translated into improved performance in the OR. Such studies are difficult and expensive to conduct and also have ethical constraints (i.e. having a control group of less well trained doctors treating patients). Further research is certainly needed but with strong evidence showing the importance of NTS in ensuring patient safety a pragmatic approach is to integrate NTS training into the curriculum while continuing to investigate the impact this has on real OR performance (Fig. 3).

5. Simulation in assessment

Simulation has been used in assessment for many years in Objective Structured Clinical Examinations where procedures have to be performed on models and histories taken from simulated patients. Surgeons are also familiar with being assessed during simulated scenarios as part of courses such as Advanced Trauma and Life Support.

The use of surgical simulators to guide performance based curricular is one of the strengths of simulation-based training and is supported by many authors.[17] By evaluating performance learners can move through the curriculum at their own pace rather than assuming competence based only on the number of training hours.

Using surgical simulators in high stakes, summative assessment is more controversial, however simulation is being increasingly used for this purpose. For example in the UK, trainee selection for national residency programs includes a skills station that has included simulated ureteric stent insertion, simulated cystoscopy and basic knot tying skills. When using simulators for these types of assessment the two questions that must be asked is: how does this add to the whole assessment process, and how does it compare to other available tests. There is an extensive body of literature on the evaluation of assessment tools and simulation must be assessed by several psychometric criteria to compare it to other available tests. These include validity (for which the studies in Table 2 are useful), reliability, feasibility, educational impact, acceptability and cost-effectiveness – all of these should be considered within the context of the entire assessment process.[42]

6. The future of simulation based training

Simulation based training can teach surgeons without harming patients, and there is excellent evidence supporting its use in the early part of the surgical learning curve. Trainers are now faced with the challenge of integrating simulation training into the urology curriculum in a way that can enhance the performance of urologists and surgical teams to ultimately improve patient outcomes.

As well as implementing training there is a continuing need for research. Randomised controlled studies have shown that simulation can work – the question that is starting to be asked is *how* does it work and *how* can simulation training be optimised? This is a complex question as learning is not just dependent on the simulator but on how it is used and in what context.[43] The simulation literature has been criticised for not relating research to established learning theories – without an understanding of how learning occurs it is difficult to design studies to evaluate how to enhance learning.[44,45] There is a vast research base in fields such as psychology, motor learning, and the social sciences and several groups are already using expertise in these fields to inform their studies. With further research we may better understand how to use simulation to optimise learning and help trainees to transfer the skills they learn safely on simulators into the complex, and often stressful OR environment.

7. Conclusions

Simulation in urology is becoming an important part of surgical training. There is good evidence for the utility of part task simulators to shorten the learning curve in an environment that does not compromise patient safety. There is also evidence that non-technical skills affect patient outcomes in the operating room and that high fidelity team based simulation training can improve NTS and team performance. This evidence has helped to strengthen the argument by surgical educators who feel that simulation should be formally incorporated into the urology curriculum.

Ethical approval

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Author contribution

James Brewin – concept and writing.
Kamran Ahmed – writing and editing.
Ben Challacombe – concept and editing.

Conflict of interest

The authors have declared that no conflict of interest exists.

References

1. Darzi A. *Saws and scaples to lasers and robots – advances in surgery*. London: Department of Health; 2007.
2. Mundy AR. The future of urology. *BJU Int* 2003 Sep;**92**(4):337–9. PubMed PMID: 12930411. [Epub 2003/08/22. eng].
3. Gawande AA, Zinner MJ, Studdert DM, Brennan TA. Analysis of errors reported by surgeons at three teaching hospitals. *Surgery* 2003 Jun;**133**(6):614–21. PubMed PMID: 12796727.
4. Reznick RK, MacRae H. Teaching surgical skills–changes in the wind. *N Engl J Med* 2006 Dec 21;**355**(25):2664–9. PubMed PMID: 17182991. [Epub 2006/12/22. eng].
5. Scott DJ, Dunnington GL. The new ACS/APDS skills curriculum: moving the learning curve out of the operating room. *J Gastrointest Surg* 2008 Feb;**12**(2):213–21. PubMed PMID: 17926105. [Epub 2007/10/11. eng].
6. Aggarwal R, Darzi A. From scalpel to simulator: a surgical journey. *Surgery* 2009 Jan;**145**(1):1–4. PubMed PMID: 19081469. [Epub 2008/12/17. eng].
7. Le CQ, Lightner DJ, VanderLei L, Segura JW, Gettman MT. The current role of medical simulation in american urological residency training programs: an assessment by program directors. *J Urol* 2007 Jan;**177**(1):288–91. PubMed PMID: 17162066.
8. Chopra S, Kroeze S, Mayer E, Aggarwal R, Darzi A, Patel A. Virtual reality simulator – answer to training needs of European urology residents. *Eur Urol Suppl* 2008;**7**(3):259.
9. ACGME. *Program requirements of graduate medical education in surgery*. Residency Review Committee. Chicago, IL: Accreditation Council for Graduate Medical Education; 2008.
10. Hamilton EC, Scott DJ, Fleming JB, et al. Comparison of video trainer and virtual reality training systems on acquisition of laparoscopic skills. *Surg Endosc* 2002 Mar;**16**(3):406–11. PubMed PMID: 11928017.
11. Grantcharov TP, Kristiansen VB, Bendix J, Bardram L, Rosenberg J, Funch-Jensen P. Randomized clinical trial of virtual reality simulation for laparoscopic skills training. *Br J Surg* 2004 Feb;**91**(2):146–50. PubMed PMID: 14760660.
12. Sedlack RE, Kolars JC, Alexander JA. Computer simulation training enhances patient comfort during endoscopy. *Clin Gastroenterol Hepatol: Off Clin Pract J Am Gastroenterol Assoc* 2004 Apr;**2**(4):348–52. PubMed PMID: 15067632.
13. Larsen CR, Soerensen JL, Grantcharov TP, et al. Effect of virtual reality training on laparoscopic surgery: randomised controlled trial. *Bmj* 2009;**338**. b1802. PubMed PMID: 19443914. Pubmed Central PMCID: 3273782.
14. Kallstrom R, Hjertberg H, Svanvik J. Impact of virtual reality-simulated training on urology residents' performance of transurethral resection of the prostate. *J Endourol/Endourol Soc* 2010 Sep;**24**(9):1521–8. PubMed PMID: 20677993.
15. Franzeck FM, Rosenthal R, Muller MK, et al. Prospective randomized controlled trial of simulator-based versus traditional in-surgery laparoscopic camera navigation training. *Surg Endosc* 2012 Jan;**26**(1):235–41. PubMed PMID: 21853391.
16. Forster JA, Browning AJ, Paul AB, Biyani CS. Surgical simulators in urological training – views of UK Training Programme Directors. *BJU Int* 2012 Jan 11. PubMed PMID: 22233327. [Epub 2012/01/12. Eng].
17. Ahmed K, Amer T, Challacombe B, Jaye P, Dasgupta P, Khan MS. How to develop a simulation programme in urology. *BJU Int* 2011 Dec;**108**(11):1698–702. PubMed PMID: 21871051.
18. Shamim Khan M, Ahmed K, Gavazzi A, et al. Development and implementation of centralized simulation training: evaluation of feasibility, acceptability and construct validity. *BJU Int* 2013 Mar;**111**(3):518–23. PubMed PMID: 22928639.
19. Vassiliou MC, Dunkin BJ, Marks JM, Fried GM. FLS and FES: comprehensive models of training and assessment. *Surg Clin North Am* 2010 Jun;**90**(3):535–58. PubMed PMID: 20497825. Epub 2010/05/26. eng.
20. Rogers Jr SO, Gawande AA, Kwaan M, et al. Analysis of surgical errors in closed malpractice claims at 4 liability insurers. *Surgery* 2006 Jul;**140**(1):25–33. PubMed PMID: 16857439.
21. CMO. *Annual report. Safer medical practice: machines manikins and polo mints*; 2008.
22. Youngson GG, Flin R. Patient safety in surgery: non-technical aspects of safe surgical performance. *Patient Saf Surg* 2010;**4**(1):4. PubMed PMID: 20298538. [Epub 2010/03/20. eng].
23. McGaghie WC, Issenberg SB, Petrusa ER, Scalese RJ. A critical review of simulation-based medical education research: 2003-2009. *Med Educ* 2010 Jan;**44**(1):50–63. PubMed PMID: 20078756.
24. McDougall EM. Validation of surgical simulators. *J Endourol/Endourol Soc* 2007 Mar;**21**(3):244–7. PubMed PMID: 17444766.
25. Schout BM, Hendrikx AJ, Scheele F, Bemelmans BL, Scherpbier AJ. Validation and implementation of surgical simulators: a critical review of present, past, and future. *Surg Endosc* 2010 Mar;**24**(3):536–46. PubMed PMID: 19633886. Pubmed Central PMCID: 2821618.
26. Van Nortwick SS, Lendvay TS, Jensen AR, Wright AS, Horvath KD, Kim S. Methodologies for establishing validity in surgical simulation studies. *Surgery* 2010 May;**147**(5):622–30. PubMed PMID: 20015529.
27. Schout BM, Hendrikx AJ, Scherpbier AJ, Bemelmans BL. Update on training models in endourology: a qualitative systematic review of the literature between January 1980 and April 2008. *Eur Urol* 2008 Dec;**54**(6):1247–61. PubMed PMID: 18597924.
28. Ahmed K, Jawad M, Abboudi M, et al. Effectiveness of procedural simulation in urology: a systematic review. *J Urol* 2011 Jul;**186**(1):26–34. PubMed PMID: 21571338. [Epub 2011/05/17. eng].
29. Abboudi H, Khan MS, Aboumarzouk O, et al. Current status of validation for robotic surgery simulators – a systematic review. *BJU Int* 2013 Feb;**111**(2):194–205. PubMed PMID: 22672340.
30. Hull L, Arora S, Aggarwal R, Darzi A, Vincent C, Sevdalis N. The impact of nontechnical skills on technical performance in surgery: a systematic review. *J Am Coll Surg* 2012 Feb;**214**(2):214–30. PubMed PMID: 22200377.
31. Dickinson I, Watters D, Graham I, Montgomery P, Collins J. Guide to the assessment of competence and performance in practising surgeons. *ANZ J Surg* 2009 Mar;**79**(3):198–204. PubMed PMID: 19317789.
32. Flin R, O'Connor P, Crichton M. *Safety at the sharp end. A guide to non-technical skills*. Farnham: Ashgate Publishing Limited; 2008.
33. Sevdalis N, Davis R, Koutantji M, Undre S, Darzi A, Vincent CA. Reliability of a revised NOTECHS scale for use in surgical teams. *Am J Surg* 2008 Aug;**196**(2):184–90. PubMed PMID: 18558392.
34. Yule S, Flin R, Maran N, Rowley D, Youngson G, Paterson-Brown S. Surgeons' non-technical skills in the operating room: reliability testing of the NOTSS behavior rating system. *World J Surg* 2008 Apr;**32**(4):548–56. PubMed PMID: 18259809. [Epub 2008/02/09. eng].
35. Murray WB, Foster PA. Crisis resource management among strangers: principles of organizing a multidisciplinary group for crisis resource management. *J Clin Anesth* 2000 Dec;**12**(8):633–8. PubMed PMID: 11173002. [Epub 2001/02/15. eng].
36. Paige JT. Surgical team training: promoting high reliability with nontechnical skills. *Surg Clin North Am* 2010 Jun;**90**(3):569–81. PubMed PMID: 20497827.
37. Kassab E, Tun JK, Arora S, et al. "Blowing up the barriers" in surgical training: exploring and validating the concept of distributed simulation. *Ann Surg* 2011 Dec;**254**(6):1059–65. PubMed PMID: 21738021.
38. Wilson KA, Burke CS, Priest HA, Salas E. Promoting health care safety through training high reliability teams. *Qual Saf Health Care* 2005 Aug;**14**(4):303–9. PubMed PMID: 16076797. Epub 2005/08/04. eng.
39. Fanning RM, Gaba DM. The role of debriefing in simulation-based learning. *Simul Healthc* 2007 Summer;**2**(2):115–25. PubMed PMID: 19088616. [Epub 2007/07/01. eng].
40. Lee JY, Mucksavage P, Canales C, McDougall EM, Lin S. High fidelity simulation based team training in urology: a preliminary interdisciplinary study of technical and nontechnical skills in laparoscopic complications management. *J Urol* 2012 Apr;**187**(4):1385–91. PubMed PMID: 22341287.
41. Gettman MT, Pereira CW, Lipsky K, et al. Use of high fidelity operating room simulation to assess and teach communication, teamwork and laparoscopic skills: initial experience. *J Urol* 2009 Mar;**181**(3):1289–96. PubMed PMID: 19152929.
42. van der Vleuten CP, Schuwirth LW. Assessing professional competence: from methods to programmes. *Med Educ* 2005 Mar;**39**(3):309–17. PubMed PMID: 15733167.
43. Cannon-Bowers JA, Bowers C, Procci K. Optimizing learning in surgical simulations: guidelines from the science of learning and human performance. *Surg Clin North Am* 2010 Jun;**90**(3):583–603. PubMed PMID: 20497828.
44. Cook DA, Bordage G, Schmidt HG. Description, justification and clarification: a framework for classifying the purposes of research in medical education. *Med Educ* 2008 Feb;**42**(2):128–33. PubMed PMID: 18194162. [Epub 2008/01/16. eng].
45. Collective TD-BR. Design-based research: an emerging paradigm for educational inquiry. *Educ Res* 2003;**32**:5–8.